Contents

		Page
Chapter 1	**Geotechnical Operations and Administration**	1-3
1.1	Scope of Geotechnical Design, Construction, and Maintenance Support	1-3
1.1.1	Geotechnical Design Objectives for Project Definition Phase	1-4
1.1.2	Geotechnical Design Objectives for Project Design Phase	1-4
1.1.3	Geotechnical Design Objectives for PS&E Development Phase	1-4
1.2	Role of Offices Providing In-House Geotechnical Design, Construction, and Maintenance Support	1-5
1.2.1	Lead Role for WSDOT Regarding Geotechnical Policy and Design	1-5
1.2.2	Geotechnical Functions Delegated to the Regions	1-6
1.2.3	Coordination between HQ's and Region Regarding Emergency Response	1-8
1.3	Geotechnical Support within the Managing Project Delivery (MPD) Process	1-9
1.3.1	Initiate and Align	1-9
1.3.2	Plan the Work	1-10
1.3.3	Endorse the Plan	1-10
1.3.4	Work the Plan	1-10
1.3.5	Transition and Closure	1-11
1.3.6	Application of the MPD Process to Construction	1-11
1.3.7	Master Deliverables to be Considered	1-11
1.4	Geotechnical Report Review Process, Certification and Approval Requirements	1-14
1.4.1	Report Certification	1-15
1.4.2	Approval of Reports Produced by the HQ Geotechnical Division	1-15
1.5	Reports Produced by Consultants or other Agencies for WSDOT, and Reports Produced by Design-Builders	1-15
1.6	Geotechnical Consultant Administration	1-16
1.7	Geotechnical Information Provided to Bidders	1-19
1.7.1	Final Geotechnical Project Documentation	1-19
1.7.2	Final Geotechnical Documentation Publication	1-19
1.7.3	Geotechnical Information to be Included as Part of the Contract	1-19
1.8	Sample Retention and Chain of Custody	1-20
1.9	Geotechnical Design Policies and their Basis	1-20
1.10	Geotechnical Construction Support Policies	1-21

Page

1.11 Geotechnical Construction Submittal Review Policies 1-22
1.11.1 Proprietary Retaining Walls 1-23
1.11.2 Other Construction Submittals (Non-Proprietary walls, Excavation and Shoring, Soldier Piles, Ground Anchors, Shafts, Piles, Ground Improvement, etc.) 1-23

Appendix 1-A Preliminary Geotechnical Engineering Services Scope of Work 1-24
Appendix 1-B Geotechnical Engineering Services Scope of Work for PS&E Level Design 1-26

Chapter 2 Project Geotechnical Planning 2-3
2.1 Overview 2-3

2.2 Preliminary Project Planning 2-3
2.2.1 Overview 2-3
2.2.2 Office Review 2-4
2.2.2.1 Site Geology and Seismicity 2-4
2.2.2.2 Previous Site Exploration Data 2-6
2.2.2.3 Previous Site Use 2-7
2.2.2.4 Construction Records 2-7
2.2.3 Site Reconnaissance 2-8
2.2.3.1 General 2-8

2.3 Development of the Subsurface Exploration Plan 2-9
2.3.1 General Considerations for Preparation of the Exploration Plan 2-9
2.3.2 Criteria for Development 2-10
2.3.3 Preparing the Exploration Plan 2-13

2.4 References 2-16

Appendix 2-A Field Exploration Request Form 2-17
FIELD EXPLORATION REQUEST 2-17

Chapter 3 Field Investigation 3-3
3.1 Overview 3-3

3.2 Activities and Policies – Before Exploration 3-3

3.3 Activities and Policies – During Exploration 3-4

3.4 Activities and Policies – After Exploration 3-6

Page

Appendix 3-A Daily Drill Report Form 3-7
Appendix 3-B Field Investigation Best Management Practices for Erosion and Spill Prevention 3-9

Chapter 4 Soil and Rock Classification and Logging 4-3
4.1 Overview 4-3

4.2 Soil Classification 4-3
4.2.1 Coarse Grained Soils 4-4
4.2.2 Fine-Grained Inorganic Soils 4-7
4.2.3 Organic Fine Grained Soils 4-7
4.2.4 Angularity 4-10
4.2.5 Consistency and Relative Density 4-11
4.2.6 Color 4-11
4.2.7 Moisture 4-12
4.2.8 Structure 4-12
4.2.9 HCl Reaction 4-12
4.2.10 Test Hole Logging 4-13

4.3 Rock Classification 4-13
4.3.1 Intact Properties 4-13
4.3.1.1 Igneous Rocks 4-14
4.3.1.2 Sedimentary Rocks 4-15
4.3.1.3 Metamorphic Rocks 4-16
4.3.1.4 Rock Color 4-17
4.3.1.5 Grain Size 4-17
4.3.1.6 Weathered State of Rock 4-17
4.3.1.6 Relative Rock Strength 4-18
4.3.1.7 Slaking 4-19
4.3.2 In Situ Properties 4-19
4.3.2.1 Discontinuity Spacing 4-20
4.3.2.2 Discontinuity Condition 4-21
4.3.2.3 Core Recovery (CR) 4-21
4.3.2.4 Rock Quality Designation (RQD) 4-21
4.3.2.5 Fracture Frequency (FF) 4-22
4.3.2.6 Voids 4-22
4.3.3 Test Hole Logging 4-22

4.4 References 4-22

		Page
Chapter 5	**Engineering Properties of Soil and Rock**	5-3
5.1	Overview	5-3
5.2	Influence of Existing and Future Conditions on Soil and Rock Properties	5-3
5.3	Methods of Determining Soil and Rock Properties	5-4
5.4	In-Situ Field Testing	5-4
5.4.1	Well Pumping Tests	5-6
5.4.2	Packer Permeability Tests	5-6
5.4.3	Seepage Tests	5-6
5.4.4	Slug Tests	5-7
5.4.5	Piezocone Tests	5-7
5.4.6	Flood Tests	5-7
5.5	Laboratory Testing of Soil and Rock	5-8
5.5.1	Quality Control for Laboratory Testing	5-8
5.5.2	Developing the Testing Plan	5-9
5.6	Engineering Properties of Soil	5-10
5.6.1	Laboratory Performance Testing	5-10
5.6.2	Correlations to Estimate Engineering Properties of Soil	5-11
5.7	Engineering Properties of Rock	5-12
5.8	Final Selection of Design Values	5-13
5.8.1	Overview	5-13
5.8.2	Data Reliability and Variability	5-14
5.8.3	Final Property Selection	5-15
5.8.4	Development of the Subsurface Profile	5-16
5.8.5	Selection of Design Properties for Engineered Materials	5-17
5.9	Properties of Predominant Geologic Units in Washington	5-19
5.9.1	Loess	5-19
5.9.2	Peat/Organic Soils	5-21
5.9.3	Glacial Till and Glacial Advance Outwash	5-21
5.9.4	Colluvium/Talus	5-22
5.9.5	Columbia River Sand	5-23
5.9.6	Columbia Basin Basalts	5-23
5.9.7	Latah Formation	5-24
5.9.8	Seattle Clay	5-24
5.9.9	Bellingham Glaciomarine Drift	5-26
5.9.10	Coastal Range Siltstone/Claystone	5-27
5.9.11	Troutdale Formation	5-27

Page

5.9.12 Marine Basalts - Crescent Formation 5-27
5.9.13 Mélange Rocks on Olympic Peninsula 5-28

5.10 References 5-28

Chapter 6 Seismic Design 6-3
6.1 Seismic Design Responsibility and Policy 6-3
6.1.1 Responsibility of the Geotechnical Designer 6-3
6.1.2 Geotechnical Seismic Design Policies 6-3
6.1.2.1 Seismic Performance Objectives 6-3
6.1.2.2 Maximum Considered Depth for Liquefaction 6-4
6.1.3 Governing Design Specifications and Additional Resources 6-5

6.2 Geotechnical Seismic Design Considerations 6-6
6.2.1 Overview 6-6
6.2.2 Site Characterization 6-6
6.2.3 Information for Structural Design 6-13

6.3 Design Code Based Seismic Hazard and Site Response 6-13
6.3.1 Determination of Seismic Hazard Level 6-14
6.3.2 2004 AASHTO Site Response 6-16
6.3.3 2003 IBC for Site Response 6-16
6.3.4 Bedrock versus Ground Surface Acceleration 6-17
6.3.5 Earthquake Magnitude 6-19

6.4 Input for Structural Design 6-19
6.4.1 Foundation Springs 6-19
6.4.1.1 Shallow Foundations 6-19
6.4.1.2 Deep Foundations 6-20
6.4.2 Earthquake Induced Earth Pressures on Retaining Structures 6-20
6.4.3 Downdrag Loads on Structures 6-20
6.4.4 Lateral Spread / Slope Failure Loads on Structures 6-20
6.4.4.1 Displacement Based Approach 6-20
6.4.4.2 Force Based Approaches 6-21;
6.4.4.3 Mitigation Alternatives 6-22

6.5 Seismic Geologic Hazards 6-23
6.5.1 Fault Rupture 6-23
6.5.2 Liquefaction 6-24
6.5.2.1 Methods to Evaluate Liquefaction Potential 6-26
6.5.2.2 Minimum Factor of Safety Against Liquefaction 6-29
6.5.2.3 Liquefaction Induced Settlement 6-29
6.5.2.4 Residual Strength Parameters 6-32

Page

6.5.2.5 Flow Failures and Lateral Spreading 6-32
6.5.3 Slope Instability 6-33
6.5.3.1 Pseudo-static Analysis 6-33
6.5.3.2 Deformations 6-33
6.5.4 Settlement of Dry Sand 6-37

6.6 References 6-37

Appendix 6-A Site Specific Seismic Hazard and Site Response 6-41
6-A.1 Background Information for Performing Site Specific Analysis 6-41
6-A.1.1 Regional Tectonics 6-41
6-A.2 Design Earthquake Magnitude 6-43
6-A.3 Probabilistic and Deterministic Seismic Hazard Analyses 6-44
6-A.4 Selection of Attenuation Relationships 6-45
6-A.5 Site Specific Response Analysis 6-45
6-A.5.1 Design/Computer Models 6-45
6-A.5.2 Input Parameters for Site Specific Response Analysis 6-46

Chapter 7 Slope Stability Analysis 7-3
7.1 Overview 7-3

7.2 Development of Design Parameters and Other Input Data for Slope Stability Analysis 7-3

7.3 Design Requirements 7-4

7.4 References 7-6

Chapter 8 Foundation Design 8-5
8.1 Overview 8-5

8.2 Overall Design Process for Structure Foundations 8-5

8.3 Data Needed for Foundation Design 8-7
8.3.1 Field Exploration Requirements for Foundations 8-10
8.3.2 Laboratory and Field Testing Requirements for Foundations 8-13

8.4 Foundation Selection Considerations 8-13

8.5 Overview of LRFD for Foundations 8-14

		Page
8.6	LRFD Loads, Load Groups and Limit States to be Considered	8-16
	8.6.1 Foundation Analysis to Establish Load Distribution for Structure	8-16
	8.6.2 Downdrag Loads	8-17
	8.6.3 Uplift Loads due to Expansive Soils	8-20
	8.6.4 Soil Loads on Buried Structures	8-21
	8.6.5 Service Limit States	8-21
	8.6.5.1 Tolerable Movements	8-21
	8.6.5.2 Overall Stability	8-23
	8.6.5.3 Abutment Transitions	8-24
	8.6.6 Strength Limit States	8-25
	8.6.6.1 Spread Footings	8-25
	8.6.6.2 Driven Piles	8-26
	8.6.6.3 Drilled Shafts	8-26
	8.6.7 Extreme Event Limit States	8-27
8.7	Resistance Factors for Foundation Design – Design Parameters	8-27
8.8	Resistance Factors for Foundation Design – Service Limit States	8-27
8.9	Resistance Factors for Foundation Design – Strength Limit States	8-27
	8.9.1 Resistance Factor Considerations for Spread Footings	8-32
	8.9.2 Resistance Factor Considerations for Driven Piles	8-33
	8.9.3 Resistance Factor Considerations for Drilled Shafts	8-36
8.10	Resistance Factors for Foundation Design – Extreme Event Limit States	8-38
	8.10.1 Scour	8-38
	8.10.2 Other Extreme Event Limit States	8-38
8.11	Spread Footing Design	8-39
	8.11.1 Loads and Load Factor Application to Footing Design	8-40
	8.11.2 General Footing Design Considerations	8-42
	8.11.2.1 Footing Bearing Depth	8-43
	8.11.2.2 Effective Footing Dimensions	8-44
	8.11.2.3 Bearing Stress Distributions	8-45
	8.11.2.4 Inclined Footings on Rock	8-45
	8.11.2.5 Groundwater Effects	8-45
	8.11.2.6 Nearby Structures	8-45
	8.11.3 Service Limit State Design of Footings	8-45
	8.11.3.1 Applicable Loads	8-46
	8.11.3.2 Settlement Analyses	8-46
	8.11.3.2.1 Settlement of Footings on Cohesionless Soils	8-48
	8.11.3.2.2 Settlement of Footings on Cohesive Soils	8-52
	8.11.3.2.3 Settlement of Footings on Rock	8-58

Page

8.11.3.2.4 Bearing Resistance at the Service Limit State Using Presumptive Values 8-60
8.11.4 Strength Limit State Design of Footings 8-61
8.11.4.1 Bearing Resistance of Footings on Soil 8-62
8.11.4.1.1 Theoretical Estimation of Bearing Resistance 8-63
8.11.4.1.1(a) Considerations for Punching Shear 8-68
8.11.4.1.1(b) Considerations for Footings on Slopes 8-69
8.11.4.1.1(c) Considerations for Two Layer Soil Systems – Critical Depth 8-72
8.11.4.1.1(d) Considerations for Two Layer Soil Systems – Undrained Loading 8-72
8.11.4.1.1(e) Considerations for Two Layer Soil Systems – Drained Loading 8-75
8.11.4.1.2 Semi-Empirical Estimation of Bearing Resistance 8-75
8.11.4.1.3 Plate Load Tests for Determination of Bearing Resistance in Soil 8-76
8.11.4.2 Bearing Resistance of Footings on Rock 8-77
8.11.4.2.1 Semi-Empirical Methods for Bearing on Rock 8-77
8.11.4.2.2 Analytic Method for Bearing on Rock 8-77
8.11.4.2.3 Load Test for Bearing on Rock 8-78
8.11.4.3 Strength Limit State Design of Footings for Load Eccentricity 8-78
8.11.4.4 Design of Footings to Resist Failure by Sliding 8-78
8.11.5 Extreme Event Limit State Design of Footings 8-80

8.12 Driven Pile Foundation Design 8-81
8.12.1 Loads and Load Factor Application to Driven Pile Design 8-83
8.12.2 General Considerations for Pile Foundation Geotechnical Design 8-85
8.12.2.1 Driven Pile Sizes and Maximum Resistances 8-86
8.12.2.2 Minimum Pile Spacing 8-86
8.12.2.3 Piles Through Embankment Fill 8-87
8.12.2.4 Nearby Structures 8-87
8.12.2.5 Determination of Pile Lateral Resistance 8-87
8.12.2.6 Batter Piles 8-89
8.12.3 Service Limit State Design of Pile Foundations 8-89
8.12.3.1 Settlement 8-90
8.12.3.2 Overall Stability 8-93
8.12.3.3 Horizontal Pile Foundation Movement 8-93
8.12.3.4 Settlement Due to Downdrag 8-94
8.12.3.5 Lateral Squeeze 8-94
8.12.4 Strength Limit State Geotechnical Design of Pile Foundations 8-94
8.12.4.1 Point Bearing Piles on Rock 8-95
8.12.4.1.1 Piles Driven to Soft Rock 8-95
8.12.4.1.2 Piles Driven to Hard Rock 8-95
8.12.4.2 Prediction of Pile Length for the Contract-Required Nominal Axial Resistance 8-96

Page

8.12.4.3 Nominal Axial Resistance Change after Pile Driving 8-97
8.12.4.3.1 Relaxation 8-97
8.12.4.3.2 Setup 8-98
8.12.4.4 Buoyancy 8-98
8.12.4.5 Scour 8-98
8.12.4.6 Downdrag 8-100
8.12.4.7 Determination of Nominal Axial Pile Resistance in Compression 8-102
8.12.4.7.1 Static Load Test 8-102
8.12.4.7.2 Dynamic Testing 8-105
8.12.4.7.3 Wave Equation Analysis 8-106
8.12.4.7.4 Dynamic Formula 8-107
8.12.4.7.5 Static Analysis 8-109
8.12.4.7.5(a) α-Method 8-110
8.12.4.7.5(b) β -Method 8-110
8.12.4.7.5(c) λ-Method 8-110
8.12.4.7.5(d) Tip Resistance in Cohesive Soils 8-111
8.12.4.7.5(e) Nordlund/Thurman Method in Cohesionless Soils 8-111
8.12.4.7.5(f) Using SPT or CPT in Cohesionless Soils 8-111
8.12.4.8 Resistance of Pile Groups in Compression 8-112
8.12.4.9 Uplift Resistance of Single Piles 8-114
8.12.4.10 Uplift Resistance of Pile Groups 8-114
8.12.4.11 Nominal Horizontal Resistance of Pile Foundations 8-116
8.12.5 Extreme Event Limit State Design of Pile Foundations 8-117
8.12.6 Determination of Minimum Pile Penetration 8-119
8.12.7 Determination of Rndr Used to Establish Contract Driving Criteria for Bearing 8-120
8.12.8 Pile Drivability Analysis 8-120
8.12.9 Test Piles 8-122

8.13 Drilled Shaft Foundation Design 8-122
8.13.1 Loads and Load Factor Application to Drilled Shaft Design 8-124
8.13.2 General Considerations for Drilled Shaft Geotechnical Design 8-124
8.13.2.1 Drilled Shaft Resistance 8-124
8.13.2.2 Effect of Drilled Shaft Installation Technique on Resistance 8-125
8.13.2.3 Shaft Spacing8-125
8.13.2.4 Shaft Diameter and Enlarged Bases8-126
8.13.2.5 Battered Shafts 8-126
8.13.2.6 Nearby Structures 8-127
8.13.3 Service Limit State Design of Drilled Shafts 8-127
8.13.3.1 Settlement 8-127
8.13.3.1.1 Settlement of Single Shafts8-127
8.13.3.1.2 Settlement of Shafts in Intermediate Geomaterials (IGM's) 8-132
8.13.3.1.3 Settlement of Shaft Groups 8-132

Page

8.13.3.2 Horizontal Movement of Shafts and Shaft Groups 8-133
8.13.3.3 Overall Stability 8-133
8.12.3.4 Settlement Due to Downdrag 8-133
8.13.3.5 Lateral Squeeze 8-133
8.13.4 Strength Limit State Geotechnical Design of Drilled Shafts 8-133
8.13.4.1 Groundwater Table and Buoyancy 8-133
8.13.4.2 Scour 8-133
8.13.4.3 Downdrag 8-134
8.13.4.4 Nominal Axial Bearing Resistance of Single Drilled Shafts 8-134
8.13.4.4.1 Estimation of Drilled Shaft Resistance in Cohesive Soils 8-135
8.13.4.4.1(a) Side Resistance in Cohesive Soils 8-135
8.13.4.4.1(b) Tip Resistance in Cohesive Soils 8-137
8.13.4.4.2 Estimation of Drilled Shaft Resistance in Cohesionless Soils 8-137
8.13.4.4.2(a) Side Resistance in Cohesionless Soils 8-137
8.13.4.4.2(b) Tip Resistance in Cohesionless Soils 8-139
8.13.4.4.3 Shafts in Strong Soil Overlying Weaker Compressible Soil 8-139
8.13.4.4.4 Estimation of Drilled Shaft Resistance in Rock 8-139
8.13.4.4.4(a) Side Resistance in Rock 8-140
8.13.4.4.4(b) Tip Resistance in Rock 8-141
8.13.4.4.4(c) Combined Side and Tip Resistance in Rock 8-142
8.13.4.4.5 Estimation of Drilled Shaft Resistance in Intermediate Geomaterials (IGM's) 8-143
8.13.4.4.6 Estimation of Drilled Shaft Resistance Using Load Tests 8-143
8.13.4.5 Shaft Group Resistance 8-144
8.13.4.5.1 Shaft Groups in Cohesive Soil 8-145
8.13.4.5.2 Shaft Groups in Cohesionless Soil 8-145
8.13.4.6 Shaft Uplift Resistance 8-145
8.13.4.6.1 Uplift Resistance of Single Shafts 8-145
8.13.4.6.2 Uplift Resistance of Shaft Groups 8-147
8.13.4.6.3 Load test for Shaft Uplift Resistance 8-147
8.13.4.7 Nominal Horizontal Resistance of Shaft and Shaft Group Foundations 8-147
8.13.5 Extreme Event Limit State Design of Drilled Shafts 8-148

8.14 Micropiles 8-148

8.15 Proprietary Foundation Systems 8-148

8.16 Detention Vaults 8-149
8.16.1 Overview 8-149
8.16.2 Field Investigation Requirements 8-149
8.16.3 Design Requirements 8-150

References 8-150
Appendix 8-A Approved Proprietary Foundation Systems 8-157

Page

Chapter 9 Embankments 9-3
9.1 Overview and Data Needed 9-3
9.1.1 Site Reconnaissance 9-3
9.1.2 Field Exploration and Laboratory Testing Requirements 9-3
9.1.3 Soil Sampling and Stratigraphy 9-5
9.1.4 Groundwater 9-6

9.2 Design Considerations 9-7
9.2.1 Typical Embankment Materials and Compaction 9-7
9.2.1.1 Rock Embankments 9-7
9.2.1.2 Earth Embankments and Bridge Approach Embankments 9-8
9.2.1.3 Fill Placement Below Water 9-9
9.2.2 Embankments for Detention/Retention Facilities 9-9
9.2.3 Stability Assessment 9-9
9.2.3.1 Safety Factors 9-10
9.2.3.2 Strength Parameters 9-10
9.2.4 Embankment Settlement Assessment 9-11
9.2.4.1 Settlement Impacts 9-11
9.2.4.2 Settlement Analysis 9-11
9.2.4.2.1 Primary Consolidation 9-11
9.2.4.2.2 Secondary Compression 9-12
9.2.4.3 Stress Distribution 9-12
9.2.4.3.1 Simple 2V:1H Method 9-13
9.2.4.3.2 Theory of Elasticity 9-13
9.2.4.3.3 Empirical Charts 9-14
9.2.4.3.4 Rate of Settlement 9-15
9.2.4.4 Analytical Tools 9-16

9.3 Stability Mitigation 9-16
9.3.1 Staged Construction 9-16
9.3.1.1 Design Parameters 9-18
9.3.1.2 In-Situ Shear Strength and Determination of Stability Assuming Undrained Loading 9-18
9.3.1.3 Total Stress Analysis 9-20
9.3.1.4 Effective Stress Analysis 9-23
9.3.2 Base reinforcement 9-26
9.3.3 Ground Improvement 9-27
9.3.4 Lightweight Fills 9-27
9.3.4.1 Geofoam 9-28
9.3.4.2 Lightweight Aggregates 9-28
9.3.4.3 Wood Fiber 9-28
9.3.4.4 Scrap (Rubber) Tires 9-28
9.3.4.5 Light Weight Cellular Concrete 9-29
9.3.4.6 Toe Berms and Shear keys 9-29

Page

9.4 Settlement Mitigation 9-29
9.4.1 Acceleration Using Wick Drains 9-29
9.4.2 Acceleration Using Surcharges 9-30
9.4.3 Lightweight Fills 9-31
9.4.4 Over-excavation 9-31

9.5 Construction Considerations and PS&E Development 9-31
9.5.1 Settlement and Pore Pressure Monitoring 9-32
9.5.2 Instrumentation 9-32
9.5.2.1 Piezometers 9-32
9.5.2.2 Instrumentation for Settlement 9-33
9.5.2.2.1 Settlement Plates 9-33
9.5.2.2.2 Pneumatic Settlement Cells 9-33
9.5.2.2.3 Sondex System 9-33
9.5.2.2.4 Horizontal Inclinometer 9-34
9.5.3 PS&E Considerations 9-34
9.5.4 PS&E Checklist 9-34

9.6 References 9-34

Appendix 9-A Examples Illustrating Staged Fill Construction Design 9-37
9-A.1 Problem Setup 9-37
9-A-2 Determination of Maximum Stable First Stage Fill Height 9-39
9-A.2 Total Stress Analysis Procedure Example 9-39
9-A.3 Effective Stress Analysis Procedure Example 9-45

Chapter 10 Soil Cut Design 10-3
10.1 Overview and Data Acquisition 10-3
10.1.1 Overview 10-3
10.1.2 Site Reconnaissance 10-3
10.1.3 Field Exploration 10-4
10.1.3.1 Test Borings 10-4
10.1.3.2 Sampling 10-4
10.1.3.3 Groundwater Measurement 10-5
10.1.4 Laboratory Testing 10-5

10.2 Overall Design Considerations 10-6
10.2.1 Overview 10-6
10.2.2 Design Parameters 10-7

10.3 Soil Cut Design 10-7
10.3.1 Design Approach and Methodology 10-7

Page

10.3.2 Seepage Analysis and Impact on Design 10-9
10.3.3 Drainage Considerations and Design 10-9
10.3.4 Stability Improvement Techniques 10-10
10.3.5 Erosion and Piping Considerations 10-11

10.4 Use of Excavated Materials 10-12

10.5 Special Considerations for Loess 10-13

10.6 PS&E Considerations 10-20

10.7 References 10-20

Appendix 10-A Washington State Department of Transportation Loess Slope Design Checklist 10-23

Chapter 11 Ground Improvement 11-3
11.1 Overview 11-3

11.2 Development of Design Parameters and Other Input Data for Ground Improvement Analysis 11-3

11.3 Design Requirements 11-4

11.4 References 11-5

Chapter 12 Rock Cut Design 12-3
12.1 Overview 12-3

12.2 Development of Design Parameters and Other Input Data for Rock Cut Stability Analysis 12-3

12.3 Design Requirements 12-3

12.4 References 12-3

Page

Chapter 13 Landslide Analysis and Mitigation 13-3
13.1 Overview 13-3

13.2 Development of Design Parameters and Other Input Data for Landslide Analysis 13-3

13.3 Design Requirements 13-3

13.4 References 13-3

Chapter 14 Unstable Rockslope Analysis and Mitigation 14-3
14.1 Overview 14-3

14.2 Development of Design Parameters and Other Input Data for Unstable Rockslope Analysis 14-3

14.3 Design Requirements 14-3

14.4 References 14-3

Chapter 15 Abutments, Retaining Walls, and Reinforced Slopes 15-5
15.1 Introduction 15-5

15.2 Definitions 15-6

15.3 Required Information 15-7
15.3.1 Site Data and Permits 15-7
15.3.2 Geotechnical Data Needed for Retaining Wall and Reinforced Slope Design 15-7
15.3.3 Site Reconnaissance 15-9
15.3.4 Field Exploration Requirements 15-10
15.3.4.1 Exploration Type, Depth, and Spacing 15-11
15.3.4.2 Walls and Slopes Requiring Additional Exploration 15-12
15.3.4.2.1 Soil Nail Walls 15-12
15.3.4.2.2 Walls with Ground Anchors or Deadmen Anchors 15-12
15.3.4.2.3 Wall or Slopes with Steep Back Slopes or Steep Toe Slopes 15-12
15.3.5 Field, Laboratory, and Geophysical Testing for Abutments, Retaining Walls, and Reinforced Slopes 15-13
15.3.6 Groundwater 15-14

15.4 General Design Requirements 15-14
15.4.1 Design Methods 15-14
15.4.2 Special Requirements 15-15

Page

15.4.2.1 Tiered Walls 15-15
15.4.2.2 Back-to-Back Walls 15-15
15.4.2.3 Walls on Slopes 15-16
15.4.2.4 MSE Wall Supported Abutments 15-16
15.4.2.5 Minimum Embedment 15-16
15.4.2.6 Serviceability Requirements 15-17
15.4.2.7 Active, Passive, At-rest Earth Pressures 15-18
15.4.2.8 Surcharge Loads 15-18
15.4.2.9 Seismic Earth Pressures 15-18
15.4.2.10 Liquefaction 15-20
15.4.2.11 Overall Stability 15-20
15.4.2.12 Wall Drainage 15-20
15.4.2.13 Utilities 15-20
15.4.2.14 Guardrail and Barrier 15-21

15.5 Specific Design Requirements 15-21
15.5.1 Abutments and Standard Plan Walls 15-21
15.5.2 Nongravity Cantilever and Anchored Walls 15-21
15.5.2.1 Nongravity Cantilever Walls 15-22
15.5.2.2 Anchored/Braced Walls 15-22
15.5.2.3 Permanent Ground Anchors 15-23
15.5.2.4 Deadmen 15-26
15.5.3 Mechanically Stabilized Earth Walls 15-28
15.5.3.1 Internal Stability Using K-Stiffness Method 15-28
15.5.3.1.1 K-Stiffness Method Loads and Load Factors 15-28
15.5.3.1.2 K-Stiffness Method Resistance Factors 15-30
15.5.3.1.3 Safety Against Structural Failure (Internal Stability) 15-31
15.5.3.1.4 Strength Limit State Design for Internal Stability Using the K-Stiffness Method – Geosynthetic Walls 15-38
15.5.3.1.5 Strength Limit State Design for Internal Stability Using the K-Stiffness Method – Steel Reinforced Walls 15-41
15.5.3.1.6 Seismic Design for Internal Stability Using the K-Stiffness Method 15-43
15.5.3.1.7 Design Sequence Considerations for the K-Stiffness Method 15-43
15.5.4 Prefabricated Modular Walls 15-44
15.5.5 Rock Walls 15-44
15.5.6 Reinforced Slopes 15-44
15.5.7 Soil Nail Walls 15-45

15.6 Temporary Shoring 15-46
15.6.1 Overview 15-46
15.6.1.1 Purpose of Temporary Shoring 15-47
15.6.2 Temporary Cut Slopes 15-47
15.6.3 Types of Temporary Retaining Systems 15-49

Page

15.6.3.1 Fill Applications 15-49
15.6.3.1.1 MSE Walls 15-49
15.6.3.1.2 Prefabricated Modular Block Walls 15-49
15.6.3.2 Common Cut Applications 15-50
15.6.3.2.1 Trench Boxes 15-50
15.6.3.2.2 Sheet Piling 15-50
15.6.3.2.3 Soldier Piles 15-51
15.6.3.2.4 Modular Block Walls 15-52
15.6.3.2.5 Braced Cuts 15-52
15.6.3.2.6 Soil Nail Walls 15-52
15.6.3.3 Uncommon Shoring Systems for Cut Applications 15-53
15.6.3.3.1 Diaphragm/Slurry Walls 15-53
15.6.3.3.2 Secant Pile Walls 15-53
15.6.3.3.3 Cellular Cofferdams 15-54
15.6.3.3.4 Frozen Soil Walls (Ground Freezing) 15-54
15.6.3.3.5 Deep Soil Mixing 15-55
15.6.3.3.6 Permeation Grouting 15-55
15.6.3.3.7 Jet Grouting 15-56
15.6.4 Geotechnical Data Needed for Design 15-56
15.6.5 Factors Influencing Choice of Temporary Shoring 15-56
15.6.5.1 Application 15-57
15.6.5.2 Cut/fill Height 15-57
15.6.5.3 Soil Conditions 15-57
15.6.5.3.1 Dense Soils and Obstructions 15-57
15.6.5.3.2 Caving Conditions 15-57
15.6.5.3.3 Permeability 15-57
15.6.5.3.4 Bottom Heave and Piping 15-58
15.6.5.3.5 High Locked in Lateral Stresses 15-58
15.6.5.3.6 Compressible Soils 15-58
15.6.5.4 Groundwater 15-58
15.6.5.5 Space Limitations 15-58
15.6.5.6 Adjacent Infrastructure 15-59
15.6.6 General Design Considerations 15-59
15.6.6.1 Design Approach/Resistance Factors 15-59
15.6.6.2 Design Loads 15-60
15.6.7 Construction Considerations 15-60

15.7 References 15-60

Appendices

15-A Preapproved Proprietary Wall and Reinforced General Design Requirements 15-A
15-B Preapproved Proprietary Wall/Reinforced Slope Design and Construction Review Checklist 15-B

15-C HITEC Earth Retaining Systems Evaluation for MSE Wall and Reinforced Slope Systems, as Modified for WSDOT Use: Submittal Requirements 15-C
15-D Preapproved Proprietary Wall Systems 15-D

Preapproved Wall Appendix: Specific Requirements and Details for LB Foster Retained Earth Concrete Panel Walls 15-1

Preapproved Wall Appendix: Specific Requirements and Details for Eureka Reinforced Soil Concrete Panel Walls 15-11

Preapproved Wall Appendix: Specific Requirements and Details for Hilfiker Welded Wire Faced Walls 15-15

Preapproved Wall Appendix: Specific Requirements and Details for KeySystem I Walls 15-21

Preapproved Wall Appendix: Specific Requirements and Details for Tensar MESA Walls 15-31

Preapproved Wall Appendix: Specific Requirements and Details for T-WALL® (The Neel Company) 15-51

Preapproved Wall Appendix: Specific Requirements and Details for Reinforced Earth (RECO) Concrete Panel Walls 15-67

Preapproved Wall Appendix: Specific Requirements and Details for SSL Concrete Panel Walls 15-117

Preapproved Wall Appendix: Specific Requirements and Details for Tensar ARES Walls 15-125

Preapproved Wall Appendix: Specific Requirements and Details for Nelson Walls 15-145

Chapter 16 Geosynthetic Design 16-3
16.1 Overview 16-3

16.2 Development of Design Parameters for Geosynthetic Application 16-3

16.3 Design Requirements 16-4

16.4 References 16-4

Page

Chapter 17 Foundation Design for Signals, Signs, Noise Barriers, Culverts, and Buildings 17-3

17.1 General 17-3
17.1.1 Overview 17-3
17.1.2 Site Reconnaissance 17-3
17.1.3 Field Investigation 17-3

17.2 Foundation Design Requirements for Cantilever Signals, Strain Poles, Cantilever Signs, Sign Bridges, and Luminaires - General 17-6
17.2.1 Design by Correlation for Cantilever Signals, Strain Poles, Cantilever Signs, Sign Bridges, and Luminaires 17-6
17.2.2 Special Design for Cantilever Signals, Strain Poles, Cantilever Signs, Sign Bridges, and Luminaires 17-9
17.2.3 Cantilever Signals and Strain Pole Standards 17-9
17.2.3.1Overview 17-9
17.2.3.2 Standard Foundation Designs 17-10
17.2.3.3 Construction Considerations 17-10
17.2.4 Cantilever and Sign Bridges 17-10
17.2.4.1 Overview 17-10
17.2.4.2 Standard Foundation Designs 17-11
17.2.4.3 Construction Considerations 17-11
17.2.5 Luminaires (Light Standards) 17-12
17.2.5.1 Overview 17-12
17.2.5.2 Standard Foundation Design 17-12
17.2.5.3 Construction Considerations 17-12

17.3 Noise Barriers 17-12
17.3.1 Overview17-12
17.3.4 Foundation Design Requirements for Noise Barriers 17-12
17.3.4.1 Spread Footings 17-13
17.3.4.2 Shaft Foundations 17-14
17.3.4.3 Non-Standard Foundation Design 17-16
17.3.3 Construction Considerations 17-17

17.4 Culverts 17-17
17.4.1 Overview 17-17
17.4.2 Culvert Design and Construction Considerations 17-17

17.5 Buildings 17-18
17.5.1 Overview 17-18
17.5.2 Design Requirement for Buildings 17-18

17.6 References 17-21

Page

Chapter 18 Geotechnical Design for Marine Structure Foundations 18-3
18.1 Overview 18-3

18.2 References 18-3

Chapter 19 Infiltration Facility Design 19-3
19.1 Overview 19-3

19.2 Geotechnical Investigation and Design for Infiltration Facilities 19-3

19.3 References 19-3

Chapter 20 Unstable Slope Management 20-3
20.1 Overview 20-3

20.2 References 20-3

Chapter 21 Materials Source Investigation and Report 21-3
21.1 Overview 21-3

21.2 Material Source Geotechnical Investigation 21-3

21.3 Materials Source Report 21-6

Chapter 22 Geotechnical Baseline Reports Produced for Design-Build Projects 22-3
22.1 Definition 22-3

22.2 Policy – Field Investigation Requirements for the GBR 22-3

22.3 Policy – Level of Geotechnical Design and GBR Contents in Consideration of Risk Mitigation 22-6

22.4 Policy – Geotechnical Investigation During RFP Advertisement 22-7

22.5 Discussion 22-7

Appendix 22-A Example Supplemental Geotechnical Boring Program Provisions 22-9

		Page
Chapter 23	**Geotechnical Reporting and Documentation**	23-3
23.1	Overview and General Requirements	23-3
23.2	Report Certification and General Format	23-3
23.2	Geotechnical Division Report Content Requirements	23-10
	23.2.1 Conceptual or Preliminary Level Geotechnical Reports	23-10
	23.2.2 Final Geotechnical Design Reports	23-11
	23.2.3 Special Reporting Requirements for LRFD Foundation and Wall Designs	23-14
	23.2.3.1 Footings	23-14
	23.2.3.2 Drilled Shafts	23-16
	23.2.3.3 Piles	23-18
	23.2.3.4 Retaining Walls	23-20
23.3	Information to Be Provided in the Geotechnical Design File	23-24
	23.3.1 Documentation for Conceptual Level Geotechnical Design	23-25
	23.3.2 Documentation for Final Geotechnical Design	23-25
	23.3.3 Geotechnical File Contents	23-26
23.4	Consultant Geotechnical Reports and Documentation Produced on Behalf of WSDOT	23-27
23.5	Summary of Geotechnical Conditions	23-27
Appendix 23-A	PS&E Review Checklist	23-31
Appendix 23-B	Typical Design Cross-Section for a Deep Foundation	23-37